The Font-Size Effect on Judgments of Learning: A Perceptual Contrast Account

Bowen Wan[1], Jinlian Zha[2], Xiaoqian Zheng[1], and Haifeng Li[1]

[1]School of Psychology, Fujian Normal University, Fuzhou 350117, China

[2]Pingxiang Health Vocational College, Pingxiang 337000, China

Author Note

Bowen Wan: https://orcid.org/0000-0002-6705-4922

Jinlian Zha: https://orcid.org/0000-0003-3200-1705

Xiaoqian Zheng: https://orcid.org/0000-0003-2840-5029

Haifeng Li: https://orcid.org/0000-0002-8370-4868

Correspondence concerning this article should be addressed to Haifeng Li, Fujian Normal University, 1 Keji Road, Minhou District, Fuzhou, 350117, China. Email: lihaifengqiqi@163.com. Tel: 86-17805930972.

Abstract

The font-size effect on judgments of learning (JOLs) refers to that when required to predict memory performance during the study phase, participants believe that large font words are more memorable than small ones. This study proposed a perceptual contrast account to explain this effect. In Experiment 1, perceptual contrast was achieved by inserting a word with a different font (e.g., 18-pt word) into a sequence of words with the same font (e.g., 70-pt words) at a certain frequency. In Experiment 2, perceptual contrast was manipulated by presenting two different font words up and down in a pair. The results showed that: (1) a low rate of perceptual contrast as small as 25% could lead to the font-size effect on JOLs; (2) compared with the same font words with and without contrast, perceptual contrast reduced the JOLs of small ones but did not affect the JOLs of large ones. Perceptual contrast account can explain the font-size effect on JOLs that can be explained by the fluency theory and belief theory. It is also applicable to research exploring how other perceptual cues affect JOLs, e.g., number of presentations, difficulty, relatedness, and clarity.

Keywords: perceptual contrast; font size; judgments of learning; memory

Significance Statement

Does the font size of words influence your prediction on memory (Judgments of learning, JOLs)? Previous studies showed a metamemory illusion about font size that people predicted large font (e.g., 18 pt) words were remembered better than small (e.g., 48 pt) ones, but their actual memory performance had no difference between these two font words. Two theories could explain this phenomenon. The fluency theory holds that people give large font words with higher JOLs because larger ones are processed more fluently than small ones. The belief theory suggests that people may have a pre-existing belief that large font words will be remembered better than small ones. We propose that fluency and belief about font size may be based on perceptual contrast, although the font size has no practical guiding significance for actual memory. Perceptual contrast makes people realize that font size is a useful cue to guide their JOLs. Therefore, in two experiments, we proved that only when perceptual contrast was available, font size could impact JOLs. Moreover, we found that perceptual contrast significantly reduced people's JOLs of small font words, but did not significantly increase the JOLs of large ones compared with the no-contrast condition. This result can explain how perceptual contrast leads to the font size effect on JOLs. We suggest that people should pay more attention to the factors beneficial to the learning effect, such as memory coding, memory trace, etc., rather than the factors that may produce metamemory illusion, such as font size, clarity etc.

1 Introduction

The metamemory illusion about font size, first reported by Rhodes and Castel (2008), refers to people having higher confidence or predicting a higher possibility of recalling large than small font words, but font size has no impact on actual recall performance. Here we differentiate the font-size effect on JOLs, which refers to the effect that the JOLs of large font words are higher than those of small ones, with the font-size effect on memory which refers to the effect that large font words are remembered better than small ones. Researchers have proposed two theories to explain the font-size effect on JOLs. The fluency theory holds that the ease of processing of the word leads to a subjective experience of familiarity, influencing memory judgments directly and unconsciously (Jacoby et al., 1989; Koriat & Bjork, 2006). Evidence indicated that items with more fluent processing led to higher JOLs (e.g., Hertzog et al., 2003; Koriat, 2008; Matvey et al., 2001; Undorf & Erdfelder, 2011). Although some studies found no differences in processing fluency between large and small font words as measured by lexical decision or study time (Mueller et al., 2014; Su et al., 2018), researchers in a continuous identification task found that the processing of large font words was more fluent than that of small ones (Yang et al., 2018). Therefore, higher JOLs of large than small font words is due to more fluent processing of large than small font words.

The belief theory proposes that people have an inherent belief that large font words will be remembered better than small ones (Mueller & Dunlosky, 2017). Such a belief may be developed prior to the experiment, or it may be developed when people are asked to consider how font size could potentially influence memory (Mueller et al., 2014). To test this hypothesis, researchers adopted a learner-observer paradigm (Hu et al., 2015) or pre-learning

judgment paradigm (Mueller et al., 2014; Mueller et al., 2016; Price & Harrison, 2017), and found that even when people acted as an observer to observe other learner's learning process or made JOLs before learning, they still held such a belief. Most researchers agreed that both fluency and beliefs about memory mediated the font-size effect on JOLs.

Since both theories can explain the font-size effect on JOLs, is there possible a unified account underlying and integrating these two theories? In studies that have shown the font-size effect of JOLs, researchers typically asked participants to learn and rate the JOLs of different font words that are intermixed in the same list (e.g., Hu et al., 2015; Kornell et al., 2011; Rhodes & Castel, 2008; Yang et al., 2018; Undorf & Zimdahl, 2019). When the font of the learned words changes, participants will be aware of this change. This font size change will in turn affect their JOLs intentionally or unintentionally. In other words, they may compare the JOLs of the previous word with the JOLs of the successive word, and this comparison is affected by their awareness of the font size change. This inference is consistent with the cue-utilization framework that JOLs are inferential and comparative in nature (Koriat, 1997). In making judgments, people always search for cues to guide their prediction on subsequent memory performance but do not monitor their learning. When different font sizes are presented continuously, the font size cue becomes easier to use than other cues.

Here we propose a perceptual contrast account to explain the font-size effect on JOLs. Perceptual contrast is defined as a process of comparing objects with different physical or mental properties, e.g., large vs. small, hot vs. cold, or difficulty vs. easy (Helson, 1964). We derived this account from the *contrast effect* in consumer psychology. The *contrast effect*

refers to that as the processing difficulty of the first product increases, evaluations of the second product will become more favorable (Shen et al., 2010). We proposed that font size of the first word will affect the JOLs of the second word. Perceptual contrast enables participants to use the font size cue to guide their JOLs, resulting in the font-size effect on JOLs. However, when perceptual contrast is unavailable, participants are unable to utilize the font size cue but can only search for other cues to help them make JOLs, such as encoding cue, retrieval cue, or memory trace.

We can integrate the fluency and belief theories into the perceptual contrast account. Perceptual contrast makes people feel that large font words are processed more fluently than small ones. In this case, perceptual contrast serves as a reminder to participants that the font size may be an effective cue to guide their memory prediction. Or perceptual contrast makes people develop a belief that large font words will be remembered better than small ones. We argue that belief about how font size affects JOLs does not exist prior to the experiment but only develops when participants are asked to make judgments and realize that there are different font sizes — a perceptual contrast between different font sizes. Therefore, the perceptual contrast account is also applicable to those studies that use the learner-observer paradigm (Hu et al., 2015) or pre-learning judgment paradigm (Mueller et al., 2014; Mueller et al., 2016; Price & Harrison, 2017).

However, the studies mentioned above did not explore how people made JOLs on different font words when perceptual contrast was unavailable. Thus, it is also hard to speculate whether the fluency theory and belief theory still work or not when perceptual contrast is unavailable. A study by Susser et al. (2013) provided strong evidence to our

perceptual contrast account. They compared three conditions in their study. One was a "mixed-list" condition that large and small font words appeared in the same list, one was a "pure-list large" condition that the whole list contained only large font words, and one was a "pure-list small" condition that the list contained only small font words. They found that large font words had higher JOLs than small ones in the mixed-list condition, but large font words in the pure-list large condition had no significant JOLs difference with small font words in the pure-list small condition. In other words, the font-size effect on JOLs was diminished when perceptual contrast was unavailable. Moreover, this result did not support the fluency and belief theories because they predicted that large font words were always processed more fluently than small ones, or people should have the same pre-experiment belief that large font words will be remembered better than small ones.

Suppose that perceptual contrast leads to the font-size effect on JOLs, then how? Unfortunately, Susser et al. (2013) did not compare the JOLs difference of large font words between the mix-list and pure-list large condition and the JOLs difference of small font words between the mix-list and pure-list small condition. However, we can see a trend in the results of Figure 1 that the JOLs of large font words in the mixed-list condition are higher than in the pure-list large condition, and the JOLs of small font words in the mixed-list condition are lower than in the pure-list small condition. Therefore, similar to the *contrast effect*, it is possible that when perceptual contrast is available, this contrast increases the JOLs of large font words but decreases the JOLs of small font words compared with perceptual contrast is unavailable.

Therefore, in two experiments, this study attempted to explore whether perceptual

contrast led to the font-size effect of JOLs and how it worked. A previous study may suggest that perceptual contrast may not need to run through the whole sequence and that even occasional perceptual contrast may be sufficient to produce the font-size effect on JOLs (Dunlosky et al., 2000). Therefore, Experiment 1 manipulated the perceptual contrast by occasionally inserting words presented in a different font into a series of words with the same fonts. Previous studies usually used 18 pt as the small font and 48 pt as the large font. Considering that reducing the rate of perceptual contrast may weaken the font-size effect of JOLs, we increased the contrast effect of font size by setting 18 pt as the small font and 70 pt as the large font. In addition, perceptual contrast in previous studies and our Experiment 1 was an indirect contrast that participants compared a current studied word (a perception) with a previously learned word (a representation in working memory). To solve this problem and replicate the results, Experiment 2 presented two words in different fonts on the same interface so that participants could form a direct perceptual contrast.

According to the perceptual contrast account, we proposed the hypotheses that: (1) JOLs of large font words were higher than those of small ones when perceptual contrast is available, but no JOLs difference of these two fonts was evident when perceptual contrast is unavailable; (2) perceptual contrast increased the JOLs of large font words and decreased the JOLs of small font words compared with contrast and no-contrast conditions.

2 Experiment 1

The purpose of Experiment 1 was to investigate whether a low rate of perceptual contrast could lead to the font-size effect on JOLs and how perceptual contrast worked. Under the perceptual contrast conditions, different font words would appear in the same list.

The rate of large font to small font (or vice versa) was 1 to 4; that is, once four same font words were continuously presented, a different font word would be followed. This rate was significantly lower than that in previous studies, in which the rate was typically 1: 1. At the same time, this experiment also manipulated two no-contrast conditions that participants always learned and judged the same font words in a whole list. We proposed that a low rate of perceptual contrast could elicit the font-size effect on JOLs. Compared with the same font words under the no-contrast condition, perceptual contrast increased the JOLs of large font words and decreased the JOLs of small font words.

2.1 Methods

2.1.1 Participants

We determined the required sample size using G * power calculation. We found that to achieve the effect size of 0.25, about 24 participants were needed to observe a significant (α = 0.05) font-size effect on JOLs about 0.80. Therefore, this experiment randomly selected 36 graduate and undergraduate students from Fujian Normal University, including 12 males and 24 females, with an average age of 18.75 $\pm$ 0.05 years. All participants reported normal or corrected-to-normal vision and had not previously participated in a similar experiment. They were tested separately in a separate soundproof compartment. After finishing the experiment, students would get course credits in return.

2.1.2 Materials

The materials were 160 common nouns selected from the Modern Chinese Word Frequency Dictionary and randomly divided into four groups (each group contains 40 nouns).

There was no significant difference in word frequency, familiarity, concreteness, or stroke number among the four groups (*ps* > .05). Two groups were designed for perceptual contrast conditions: in the first group, one word in 18 pt font was inserted into a sequence of four consecutive words in 70 pt font, thus presenting a total of 32 words in 70 pt font and 8 words in 18 pt font. The first 18 pt word appeared at the third position in the sequence (see Figure 1 Block 1). The presentation of the second group was similar to that of the first group, just font size switched, with a total of 32 words in 18 pt font and 8 words in 70 pt font (see Figure 1 Block 2). The other two groups were designed for no perceptual contrast conditions: one group presented all words in 70 pt font and the other in 18 pt font. The first or last three words in each list were served as either primacy or recency buffers in all four groups. Therefore, for the final analysis under perceptual contrast conditions, there were 28 words in 70 pt font and 6 words in 18 pt font in one group, and 28 in 18 pt and 6 in 70 pt in the other group. Under no-contrast conditions, there were 34 words in 70 pt font in one group and 34 in 18 pt font in the other group.

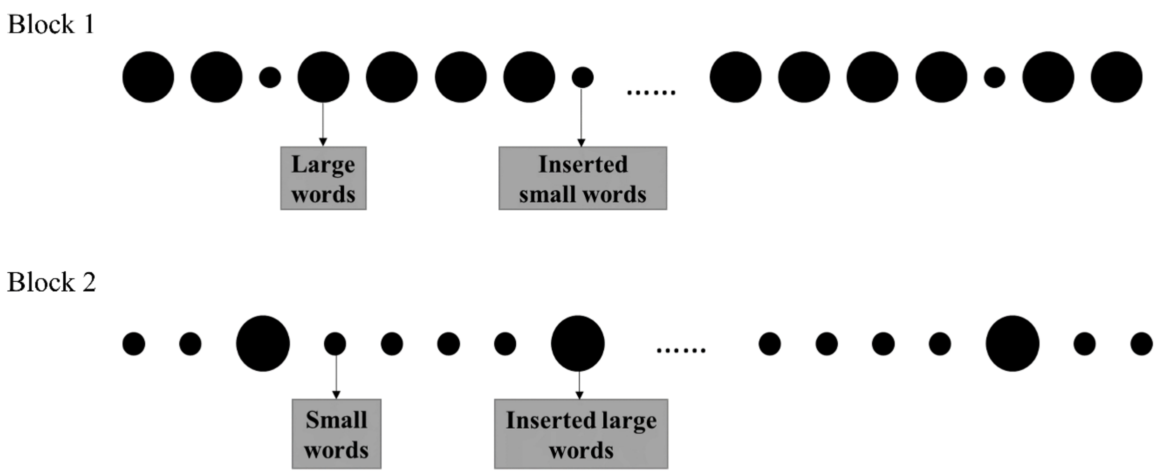

Figure 1. The words sequence under perceptual contrast conditions. Large circles refer to words in 70 pt font, and small circles refer to words in 18 pt font.

2.1.3 Procedure

All materials were presented in bold font in the center of a white screen. The experiment consisted of four blocks, each with three phases: study (during which JOLs were made), distraction, and test (free recall task). During the study phase, a 500 ms fixation was shown on the computer screen, followed by a 70 pt or 18 pt font word for 2 s. Participants were instructed to try their best to remember the words. After the word disappeared, they were asked to predict the possibility of recalling the word during the test phase by inputting a number from 0 to 100 into an input box. "0" meant they could not recall it at all, and "100" meant they could recall it at all. Participants were encouraged to use the entire range of the scale. After JOLs were made, participants were presented with an empty screen for 500 ms. After studying a list with 40 words, participants were asked to complete a 1.5-minutes continuous addition or subtraction task. Then after completing the distraction task, they were asked to recall as many words as possible and wrote the answers on a piece of paper within five minutes (no particular order required). This experiment was a 2 (font size: large, small) × 2 (perceptual contrast condition: contrast, no-contrast) within-subject experiment. A total of 4 blocks were required for each participant, and the order of the blocks was balanced between participants.

2.2 Results and Discussion

The mean JOL magnitude and recall performance of the participants in Experiment 1 are shown in Table 1. We listed the JOLs and memory performance of inserted large or small words in Table 1, but we did not analyze them. Either because each block has only six inserted large or small words or because JOLs and memory of these words are not the focus

of our analysis. However, as you can see, the inserted large or small words had the same patterns of JOLs and memory as the large or small words under the contrast conditions.

JOLs. To determine whether JOLs of these words would be affected by perceptual contrast, we conducted a 2 (font size: large, small) × 2 (perceptual contrast condition: contrast, , no-contrast) repeated-measures ANOVA on JOLs (see Figure 2). The results showed that the main effect of perceptual contrast condition was not significant, $F(1, 35) = 1.08$, $p = .307$, $\eta_p^2 = .03$. The main effect of font size was not significant, $F(1, 35) = 0.38$, $p = .542$, $\eta_p^2 = .01$. There was a significant interaction effect between font size and perceptual contrast condition, $F(1, 35) = 10.78$, $p = .002$, $\eta_p^2 = .24$. Further simple effect analysis (to compare the JOLs of large with small font words within the contrast or no-contrast condition) using Bonferroni test showed that under the contrast condition, JOLs of large font words (M = 42.66, SD = 12.63) were significantly higher than those of small ones (M = 37.57, SD = 13.26), $F(1, 35) = 9.72$, $p = .004$, $\eta_p^2 = .22$. However, JOLs had no significant difference between large (M = 40.06, SD = 13.37) and small font words (M = 43.47, SD = 17.07) under the no-contrast condition, $F(1, 35) = 2.67$, $p = .111$, $\eta_p^2 = .07$. These results indicated that perceptual contrast leads to higher JOLs of large than small font words.

To further investigate how perceptual contrast affected the JOLs of large and small font words, we conducted a simple effect analysis to compare the JOLs of the same font words between the contrast and no-contrast condition. The results showed that the JOLs of large font words had no significant difference between the two conditions, $F(1, 35) = 1.74$, $p = .196$, $\eta_p^2 = .05$. However, the JOLs of small font words under the contrast condition were significantly lower than those under the no-contrast condition, $F(1, 35) = 7.68$, $p = .009$, η_p^2

= .18. These results indicated that perceptual contrast might reduce the JOLs of small font words but did not affect the JOLs of large font words compared with the contrast and no-contrast conditions.

[insert Table 1 here]

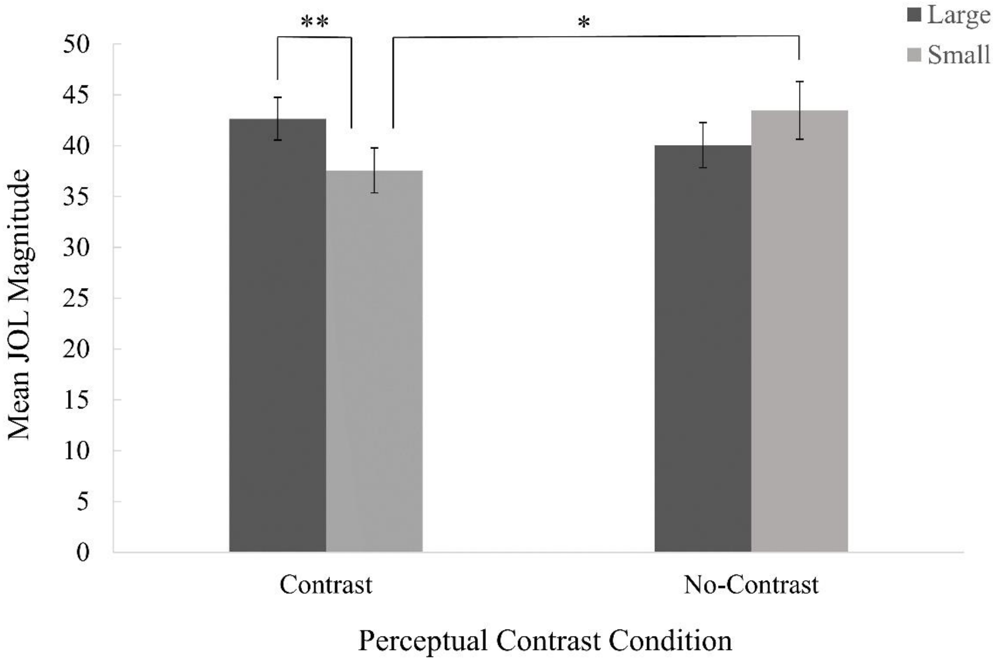

Figure 2. Mean JOL magnitude by font size and perceptual contrast condition in Experiment 1. Error bars reflect standard errors of the mean. JOL = judgment of learning. $^*p < .05$, $^{**}p < .01$.

Recall performance. A 2 (font size: large, small) × 2 (perceptual contrast condition: contrast, no-contrast) repeated-measures ANOVA on recall performance was conducted. The results showed that there was no main effect of perceptual contrast condition, $F(1, 35) = .16$, $p = .695$, $\eta_p^2 = .004$. The main effect of font size was close to significant, $F(1, 35) = 3.93$, $p = .055$, $\eta_p^2 = .10$, and an interaction effect between font size and perceptual contrast condition was close to significant, $F(1, 35) = 3.94$, $p = .055$, $\eta_p^2 = .10$. The simple effect analysis (to compare the recall performance of large with small font words within the contrast or no-contrast condition) using Bonferroni test showed that under the contrast

condition, recall performance of large font words (*M* = 0.33, *SD* = 0.16) was significantly higher than that of small ones (*M* = 0.26, *SD* = 0.16), $F(1, 35) = 8.49$, p =.006, $\eta_p^2 = .20$. However, recall performance had no significant difference between large (*M* = 0.30, *SD* = 0.12) and small font words (*M* = 0.31, *SD* = 0.16) under the no-contrast condition, $F(1, 35)$ = .02, p =.885, η_p^2 = .001. These results may indicate that perceptual contrast leads to higher recall performance of large than small font words.

To further investigate how perceptual contrast affected the recall performance of large and small font words, we conducted a simple effect analysis to compare the recall performance of the same font words between the two conditions. The results showed no differences in recall performance of both large or small font words between these two conditions.

Experiment 1 showed that under the perceptual contrast condition, participants made higher JOLs and had higher recall performance on large than small font words. However, the JOLs and recall performance of large font words were comparable to that of small font words under the no-contrast condition. These results indicated that a low rate of large to small (or small to large) font words as small as 1: 4 could also lead to higher JOLs and recall performance of large than small font words. Moreover, further analysis revealed that perceptual contrast reduced the JOLs of small font words but did not affect the JOLs of large font words compared with the contrast and no-contrast conditions. However, such a reduced effect was not observed in the recall performance.

3 Experiment 2

Experiment 1 showed that perceptual contrast might reduce the JOLs of small font

words but did not affect the JOLs of large font words, leading to higher JOLs of large than small font words. However, the perceptual contrast in Experiment 1 was an indirect perceptual contrast that participants compared the current studied word (a perception) with the previously learned word (a representation in working memory). To replicate the results of Experiment 1 and test a direct perceptual contrast, Experiment 2 presented two words in different fonts on the same interface under the contrast conditions so that participants could form a direct perceptual contrast. Participants only needed to learn and predict JOLs for one of these words. If perceptual contrast leads to higher JOLs of large than small font words, then Experiment 2 will replicate the results of Experiment 1.

3.1 Methods

3.1.1 Participants

In this experiment, 28 graduate and undergraduate students were randomly selected from Fujian Normal University. The data of one participant was excluded due to extreme JOLs (making “100” for one block), and one was excluded due to too many type errors. Finally, 26 participants were obtained, including 8 male and 18 female students, with an average age of 18.46 ± 1.07 years. All participants reported normal or corrected-to-normal vision and had not previously participated in a similar experiment. They were tested separately in a separate soundproof compartment. After finishing the experiment, students would get course credits in return.

3.1.2 Materials

The materials were 320 common nouns selected from the Modern Chinese Word

Frequency Dictionary and randomly divided into four groups (each group contained 80 nouns). There was no significant difference in word frequency, familiarity, concreteness, or stroke number of words among these four groups (*ps* > 0.05), with each pair of words arranged up and down (one above and one below the midpoint). Two of these groups were designed for perceptual contrast conditions (contrast) and the other two for no perceptual contrast conditions (no-contrast). In the groups of no-contrast conditions, words in a pair (both in the upper and lower rows) were presented in the same font, either in 70 pt (see Block 1 in Figure 3) or 18 pt font (see Block 2 in Figure 3). In the groups of contrast conditions, words in the upper row were presented in 70 pt font, and words in the lower row were presented in 18 pt font (see Block 3 in Figure 3), or words were arranged oppositely (see Block 4 in Figure 3). Participants were told to learn and make JOLs for the upper-row words while ignoring the lower-row words. In all four groups, the first three words or the last three words in each block were served as either primacy or recency buffers whose data were not calculated, so there were 34 items in each group for the final analysis.

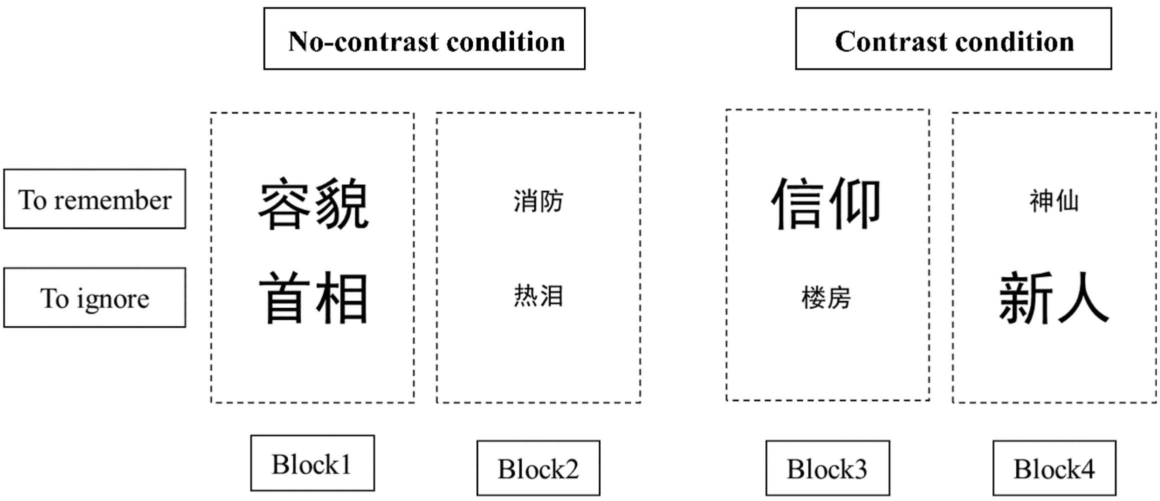

Figure 3. Examples of contrast and no-contrast conditions in Experiment 2. Participants were instructed to remember and predict only the upper-row words.

3.1.3 Procedure

On a white background screen, each pair of words were presented in bold font in two rows (one above and one below the center of the screen). Participants were told only to learn and predict the memory performance of words in the upper row. This experiment was a 2 (font size: large, small) × 2 (perceptual contrast condition: contrast, no-contrast) within-subject experiment. A total of four blocks containing 40 items were required to finish for each participant, and the order of the four blocks was balanced between participants.

3.2 Results and Discussion

The mean JOL magnitude and recall performance in Experiment 2 are shown in Table 1.

JOLs. A 2 (font size: large, small) × 2 (perceptual contrast condition: contrast, no-contrast) repeated-measures ANOVA on JOLs (see Figure 4) revealed that there was no main effect of font size, $F(1, 25) = 1.84$, $p = .187$, $\eta_p^2 = .07$, nor main effect of perceptual contrast condition, $F(1, 25) = .57$, $p = .458$, $\eta_p^2 = .02$, but there was a significant interaction effect between font size and perceptual contrast condition, $F(1, 25) = 5.84$, $p = .023$, $\eta_p^2 = .19$. Further simple effect analysis showed that, under the contrast condition, JOLs of large font words were significantly higher than those of small font words, $F(1, 25) = 4.84$, $p = .037$, $\eta_p^2 = .16$. However, JOLs of large and small font words had no significant difference between each other under the no-contrast condition, $F(1, 25) = .75$, $p = .395$, $\eta_p^2 = .03$. These results may indicate that perceptual contrast leads to higher JOLs of large than small font words.

To further investigate how perceptual contrast affected the JOLs of large and small font words, we conducted a simple effect analysis to compare the JOLs of the same font words under the contrast and no-contrast conditions. The results showed that the JOLs of large font

words had no significant difference between the contrast and no-contrast conditions, $F(1, 25) = .66$, $p = .424$, $\eta_p^2 = .03$. However, the JOLs of small font words under the contrast condition were marginally lower than those under the no-contrast condition, $F(1, 25) = 3.58$, $p = .070$, $\eta_p^2 = .13$. These results indicated a trend that perceptual contrast reduced the JOLs of small font words but did not affect the JOLs of large font words compared with the contrast and no-contrast conditions.

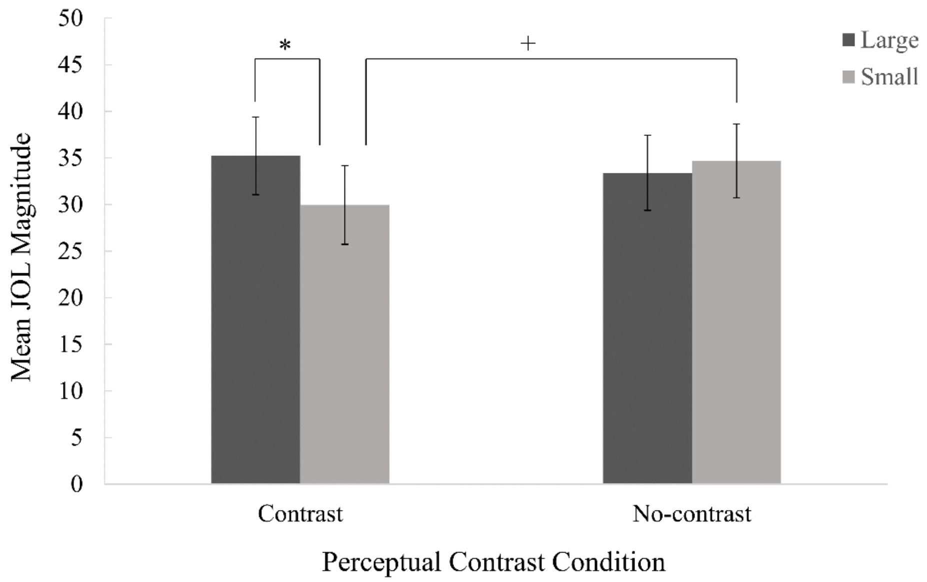

Figure 4. Mean JOL magnitude by font size and perceptual contrast condition in Experiment 2. Error bars reflect standard errors of the mean. JOL = judgment of learning. $+p = .07$, $*p < .05$.

Recall performance. In the recall task, the number of words that participants were not required to remember but were recalled was few (less than 1%). A 2 (font size: large, small) × 2 (perceptual contrast condition: contrast, no-contrast) repeated-measures ANOVA on recall performance was conducted. The results showed that there was no main effect of font size, $F(1, 25) = .05$, $p = .832$, $\eta_p^2 = .002$, nor main effect of perceptual contrast condition, $F(1, 25) = 1.01$, $p = .325$, $\eta_p^2 = .04$. However, there was a significant interaction effect

between font size and perceptual contrast condition, $F(1, 25) = 6.81$, $p = .015$, $\eta_p^2 = .21$. Further simple effect analysis showed that, under the contrast condition, recall performance of large font words was significantly higher than that of small font words, $F(1, 25) = 5.45$, $p = .028$, $\eta_p^2 = .18$. However, recall performance of large and small font words had no significant difference, $F(1, 25) = 3.12$, $p = .090$, $\eta_p^2 = .11$. These results may indicate that perceptual contrast leads to higher recall performance of large than small font words.

To further investigate how perceptual contrast affected the recall performance of large and small font words, we conducted a simple effect analysis to compare the recall performance of the same font words under the contrast and no-contrast conditions. The results showed that the recall performance of large font words had no significant difference between the contrast and no-contrast conditions, $F(1, 25) = .69$, $p = .413$, $\eta_p^2 = .03$. However, the recall performance of small font words under the contrast condition was significantly lower than that under the no-contrast condition, $F(1, 25) = .7.39$, $p = .012$, $\eta_p^2 = .23$. These results indicated that perceptual contrast reduced the recall performance of small font words but did not affect the recall performance of large font words compared with the contrast and no-contrast conditions.

Experiment 2 replicated the results of Experiment 1 that perceptual contrast led to higher JOLs of large than small font words when participants could compare words with different fonts directly. It also showed that perceptual contrast reduced the JOLs of small font words but did not affect the JOLs of large font words compared with the contrast and no-contrast conditions.

4 General discussion

This study proposed a perceptual contrast account to explain the font-size effect on JOLs. In two experiments, we tested the effectiveness of perceptual contrast on the font-size effect on JOLs. By inserting different font words into a sequence of the same font words, Experiment 1 found that a low rate of perceptual contrast as small as 25% could lead to higher JOLs of large than small font words. In addition, compared the same font words with the contrast and no-contrast conditions, perceptual contrast did not affect the JOLs of large font words but reduced the JOLs of small font words, resulting in the font-size effect on JOLs. In Experiment 2, similar results were obtained when a direct perceptual contrast was presented by presenting words in two rows (upper and lower) and only asking participants to learn and predict the upper-row words.

4.1 How perceptual contrast leads to the font-size effect on JOLs

Studies have explored how perceptual cues (especially font size) affect JOLs (Alban & Kelley, 2013; Hu et al., 2015; Mueller & Dunlosky, 2017; Mueller et al., 2016; Mueller et al., 2014; Price & Harrison, 2017), but so far, exactly how this influence occurs remains unknown. These studies typically intermixed both large and small font words in the same list and compared the JOLs of these words. However, none of these studies explored how participants rated the JOLs of large and small font words if they were tested in separate lists. In other words, previous studies have failed to consider two baseline conditions, a condition composed of pure-large font words and the other composed of pure-small font words. Therefore, without considering the baselines, none of these studies could clarify how the font size cue affects the JOLs.

Our study indicated that perceptual contrast reduced the JOLs of small font words but

did not affect the JOLs of large font words compared with contrast and no-contrast (or baseline) conditions. Influenced by perceptual contrast, participants may realize that font size may be an effective cue to evaluate their future memory, thus impacting their JOLs of words. But under the no perceptual contrast condition, no matter the words are in large or small font, participants’ JOLs are more based on the memory encoding, familiarity, or memory trace of words. Therefore, their memory predictions on these words are not affected by the font size.

Although there was no statistical difference in our study, the JOLs of large font words under the contrast conditions had a higher trend than those under no-contrast conditions. Therefore, we cannot completely conclude that the JOLs of large font words are not affected by perceptual contrast. We may say that the effect of perceptual contrast on large font words is smaller than that of small font words. Previous studies on the relationship between font size and emotion may help to explain this inference. Font size enhanced emotion effects for written emotion-related words in attention-related event-related potentials (ERPs) (Mareike et al., 2012). Small size feedback stimuli led to diminished amplitudes in both FRN and P300 components than middle and large size feedback stimuli, indicating they were perceived as less salient and were processed less deeply (Pfabigan et al., 2015). In addition, a study found that the “Pleasure” dimension of emotion increases with the font size increases in the font size range from 10 pt to 32 pt (Tsonos & Kouroupetroglou, 2016). Therefore, a possible explanation is when the font changes from small to large, people will generate pleasant emotion, while when it changes from large to small, people generate unpleasant emotion. When the font changes from small to large, people increase the JOLs of large font

words on the basis of the JOLs of small ones, whereas when the font changes from large to small, people decrease the JOLs of small font words on the basis of the JOLs of large ones. More importantly, people may have a feeling similar to loss aversion that they may be more sensitive to the unpleasure caused by the change of font from large to small than the pleasure caused by the change of font from small to large. Therefore, the increase of JOLs in large font words under pleasant emotion is smaller than the decrease of JOLs in small font words under unpleasant emotion.

4.2 Integrate the fluency theory and belief theory into the perceptual contrast account

Previous studies usually used the fluency theory and belief theory to account for the font-size effect on JOLs. The perceptual contrast account can not only explain the results that the two theories can not but also may be the underlying prerequisite for why the two theories work.

First, the fluency theory holds that large font words are easier to process than small ones, resulting in higher JOLs of large than small font words (Bjork et al., 2013; Jacoby et al., 1989; Koriat & Bjork, 2006). However, this theory fails to explain the study of Susser et al. (2013) and our study. Suppose large font words are processed more fluently than small ones, then large font words should have higher JOLs than small ones even they were learned and rated in separate lists. Susser et al. (2013) and we both found that JOLs of large font words were not different from those of small font words when they were rated in separate lists. The perceptual contrast account can fully explain these results. Perceptual contrast makes people feel that large font words are processed more fluently than small ones when

different font words are intermixed in the same list. Due to the lack of perceptual contrast, people do not feel that large font words are more fluent to process than small ones when different font words are tested in separate lists. It should be noted that the feeling about whether large font words were processed more fluently than small ones or not produced by perceptual contrast can also be interpreted as a belief. This notion is consistent with the analytic processing theory that belief about processing fluency drives the font-size effect on JOLs (Mueller & Dunlosky, 2017).

Second, the belief theory proposes that people have an inherent belief about how font size affects memory (Mueller & Dunlosky, 2017; Mueller et al., 2014). The belief theory also failed to explain the study of Susser et al. (2013) and our study. If people have the pre-experiment belief that large font words will be remembered better than small ones, then we will still observe the font-size effect on JOLs under no-contrast conditions. We argued that belief about font size affecting memory originates from perceptual contrast. When people need to rate JOLs of both large and small font words in the same list, the perceptual contrast between large and small font leads people to develop the belief that large font words are easier to remember than small ones. But when people only rate JOLs of large and small font words in separate lists, they are unable to develop such a belief. In these cases, their JOLs of words depend more on other perceptual cues, e.g., memory encoding, memory retrieval, or memory trace. Belief works only when perceptual contrast is available.

4.3 Extend perceptual contrast account to other cue effects on JOLs

The perceptual contrast account can be used to explain most studies about cue effects on JOLs. For instance, when perceptual contrast is available, JOLs are greater for words that are

generated (vs. to read) (Begg et al., 1991), words repeated twice (vs. once) (Koriat, 1997), words that are easier (vs. harder) to learn (Koriat, 1997), word-pairs that are related (vs. unrelated) (Dunlosky & Matvey, 2001), words spoken more loudly (vs. softly) (Rhodes & Castel, 2009), words that are associated with a greater (vs. lesser) physical weight (Alban & Kelley, 2013), words that are clear (vs. blurred) (Yue et al., 2013). Perceptual contrast makes people realize that the learning type, number of presentations, difficulty, relatedness, volume, implicit meaning, and clarity may be effective cues to guide their memory prediction. But when perceptual contrast is unavailable, the cue effect of JOLs may be diminished. For example, Yue et al. (2013) found that when clear words and blurred words were presented separately and tested between subjects, there was no clarity effect on JOLs.

Combining with the cue-utilization framework, the perceptual contrast also can be used to explain the studies that include multiple cues. For instance, Undorf, Söllner and Bröder (2018) found that people could integrate number of study presentations (1 vs. 2), font size (18pt vs. 48 pt), concreteness (abstract vs. concrete), and emotionality (neutral vs. emotional) in JOLs. Tatz and Peynircioğlu (2019) found that people could use font size (small vs. large), frame size (small vs. large), and word or scene clarity (clear vs. blurred) to guide their JOLs. When multiple cues are presented, perceptual contrast enables people to use them to help their memory prediction. The premise is that none of the cues can have a dominant advantage in making judgments. When it happens, people will rely on the dominant cue to make JOLs. For example, researchers found that when words were presented in a mixture of uppercase and lowercase letters (i.e., alternating format, such as PiAnO), there was no significant difference in JOLs of words between different font sizes (18 pt vs. 48 pt) in the

alternating format condition (Rhodes & Castel, 2008). In this study, the alternating format was more salient than the font size because of its uncommon. Although participants could compare the font size in different words, they still prioritized using the alternating format cue to guide their JOLs.

4.4 The font-size effect on memory

Experiments 1 and 2 both showed that perceptual contrast also led to the font-size effect on memory. That is, the recall performance of large font words was higher than that of small ones under the perceptual contrast conditions. This result was inconsistent with most previous studies that the memory performance of large and small font words had no difference (e.g., Mueller et al., 2014; Mueller et al., 2013; Rhodes & Castel, 2008; Susser et al., 2013). However, tasks in our study are different from those in previous studies.

In previous studies, the large and small font words were included in the same list, but they came from different lists in our study. Specifically, in Experiment 1 (see Figure 1), we compared the large font words from Block 1 with the small font words from Block 2. While in Experiment 2 (see Figure 3), we compared the large font words from Block 3 with the small font words from Block 4. This difference in experimental design may lead to different results between our study and previous studies.

Memory performance depends on memory strength, such as memory encoding, retrieval practice, and memory trace (Bjork et al., 2013). Perceptual contrast may lead to better memory for large than small font words, but this depends on whether it frequently disturbs the memory strength. In previous studies that showed no font-size effect on memory, participants' memory strength of words may be disturbed by the frequent change of font

sizes. However, although we designed two perceptual contrast conditions in our study, such a disturbance to memory strength is either low (Experiment 1) or does not exist (Experiment 2). Therefore, participants may successfully utilize the font size cue to guide their memory in our study. Further studies need to explore this font-size effect on memory.

5 Conclusion

This study has drawn two conclusions: (1) perceptual contrast, even a low rate as small as 25%, led to the font-size effect on JOLs. (2) Compared with the same font words with and without contrast, perceptual contrast reduced the JOLs of small ones but did not affect the JOLs of large ones. We propose the perceptual contrast account and integrate the fluency theory and belief theory to explain the font-size effect on JOLs. This account also can explain other cue effects on JOLs, e.g., number of presentations, difficulty, relatedness, and clarity.

List of abbreviations

judgments of learning: JOLs

Open Practices Statements

The data and materials for all experiments are available at https://zenodo.org/record/6243249#.YhYi0vnIRMQ, and none of the experiments was preregistered.

Declarations

Ethics approval and consent to participate

Participants in the study reported here provided informed consent and the research was approved by the Ethics Committee at School of Psychology, Fujian Normal University.

Consent for publication

Not applicable.

Availability of data and material

The datasets generated and/or analysed during the current study are available in the Zenodo respository, https://zenodo.org/record/6243249#.YhYi0vnIRMQ

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

HL, BW, and JZ conceived and designed the experiments. BW and JZ collected the data. HL, BW, JZ, and XZ analyzed the data and wrote the paper. All authors contributed to the article and approved the submitted version.

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Authors' information (optional)

[1]Fujian Normal University, Fuzhou, China [2]Pingxiang Health Vocational College, Pingxiang, China.

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Table1. Mean JOL magnitude, recall performance in contrast and no-contrast conditions from Experiments 1-2.

	Condition	Mean JOL magnitude				Recall performance			
		Large	I-small	Small	I-large	Large	I-small	Small	I-large
Exp.1	Contrast	**42.66**	**38.56**	**37.57**	**46.71**	**0.33**	**0.24**	**0.26**	**0.33**
		(12.63)	(15.42)	(13.26)	(18.63)	(0.16)	(0.17)	(0.18)	(0.17)
	No-contrast	**40.06**	/	**43.47**	/	**0.30**	/	**0.31**	/
		(13.37)		(17.07)		(0.12)		(0.16)	
Exp.2	Contrast	**35.21**	/	**29.96**	/	**0.32**	/	**0.27**	/
		(21.25)		(21.58)		(0.21)		(0.19)	
	No-contrast	**33.40**	/	**34.70**	/	**0.30**	/	**0.34**	/
		(20.55)		(20.18)		(0.18)		(0.20)	

Note. Standard deviations are reported in parentheses. I-small refers to the 18 pt font words that were inserted into the sequence of 70 pt font words in the contrast condition in Experiment 1. I-large refers to the 70 pt font words that were inserted into the sequence of 18 pt font words in the contrast condition in Experiment 1.